Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

places. For this reason the attention of Government officials has been directed to a study of the occurrence and recovery of ground water.

SUMMARY OF PHYSICAL ENVIRONMENT

The physical factors controlling the life and occupations of the inhabitants of the Navajo country are summarized in the accompanying diagram (Fig. 18), which also indicates the conditions under which Navajos and Hopis have attained their present stage of advancement and suggests the lines along which the development of the country is most likely to be successful.

(*To be concluded*)

HAWAII'S GREAT VOLCANOES AND THE STUDY OF THEM

By SIDNEY POWERS
Hawaiian Volcano Observatory

The Massachusetts Institute of Technology maintains an observatory at the volcano Kilauea, on Hawaii, under the direction of Professor T. A. Jaggar, Jr. This volcano is the most continuously active and one of the most easily accessible of any in the world. Only 22 miles away is the greatest volcano in the world, Mauna Loa, rising to a height of 13,675 feet, from which, at intervals of about ten years, comes a lava flow.

Kilauea is a low, broad dome, 4,000 feet in height, the top of which, over an area of three miles in length by two miles in breadth, is a depression with a depth of about 400 feet. The depression, or sink, has been flooded by flows for many centuries from the crater Halemaumau near one end of the sink, so that Halemaumau now forms a low inner dome. The Halemaumau crater is a smaller sink, in which a molten lava lake is almost continuously active. The rim of the inner pit rises to an elevation of 3,700 feet, which is about 300 feet above the lowest portion of the outer sink. The size of the inner crater and of the lake within varies with the phases of activity, but in 1915 the crater has been about 1,200 feet in diameter, and the lake within, at a depth of 365 feet or more, from 400 to 500 feet long, and 100 to 180 feet wide.

The lava lake in Halemaumau has been active from the spring of 1907 until the present time, with the exception of an interval from April, 1913, until May, 1914, when the lava disappeared from sight, leaving a broad, deep funnel of slide-rock through which dense volumes of sulphurous smoke issued. The lava lake has a temperature of 1000° C. (1832° F.), and consequently a thin skin of frozen lava is maintained over the yellow-red liquid. The skin is broken by fountains which break to a height of from 10 to 40 feet; by the currents which constantly provide a streaming of the lava and of the crusts; and by splashing caves at the margins of the lake. The fountains and splashing caves are caused by accumulations of gas bursting; the streaming by convection currents within the lake.

Near the center of the lake is a fountain called "Old Faithful" because of its constancy and persistency, which breaks at intervals of alternately 10-20 seconds, and 40-50 seconds. Whenever the lava lake is active in Halemaumau, Old Faithful is usually present, and although there have been lava lakes other than Halemaumau at different times, Halemaumau has generally been active when the others have been active, and always at the same location since the earliest observations. It is therefore probable that the main feeder of the lake lies under Old Faithful, and that up this feeder gas rushes to cause the fountaining.

Besides Old Faithful several other fountains are usually active in various parts of the lake, but especially near Old Faithful. These fountains all indicate uprushes of gas. Occasionally one of the fountains is active continuously for several minutes and migrates, with a violent splashing noise, toward the side of the lake, where a "cave" develops, toward which the lava streams. A cave is generally a portion of the wall built out by spatter and where gas, in uprushing, causes a steady splash for several minutes, or sometimes several hours.

The circulation within the lake is brought about by the difference in weight of the lava when full of or free from gas, and when cooler or hotter. The solidified lava is heavier than the molten. When a fountain bursts, the gas escapes and the lava becomes heavier and sinks, creating a temporary inward suction of lava and crusts. Similarly, at a splashing cave, the gas escapes and the lava—at times the whole lake—streams toward the cave.

The lava, which has lost a large part of its gas content and is partially cooled, sinks, generating a current under the surface. New gas, rising from the magma chamber below, replenishes the supply in the lava which has descended, so that this newly "vesiculated" lava rises. When the gas is evenly distributed through this lava, it rises quietly, and without fountaining, under the crusts, and may flow toward the fountaining areas or toward the caves.

The rising and expanding gas, with the chemical changes which take place within the lava, and with possibly an extensive circulation in the lava below the lake, are some of the principal factors in maintaining the heat in the molten lake, which is subject to an enormous loss of heat by radiation and convection. When the lake rises, it gradually floods the pit and the slide-rock which has come from the walls, forming a lava floor around a circular pool. If the lake rises sufficiently high, it may completely fill the Halemaumau pit, as in January, 1912, or even spill over the edge, as in 1894.

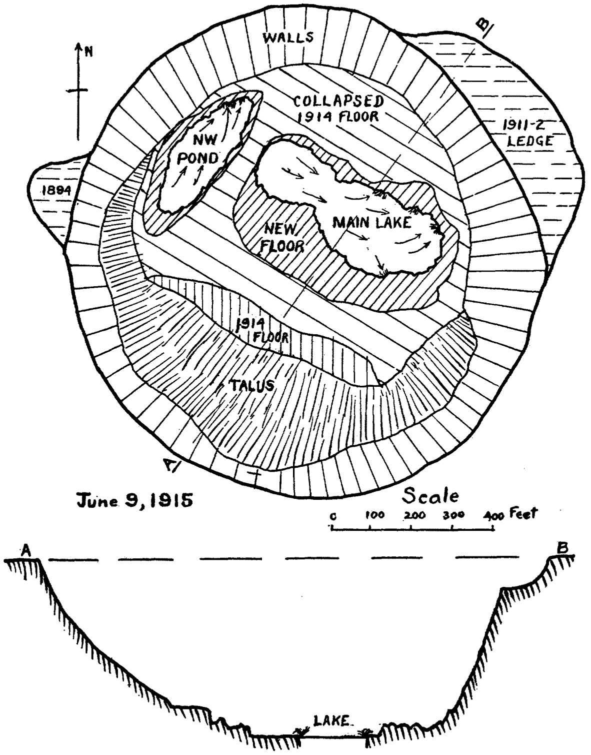

FIG. 1—The crater Halemaumau, on June 9, 1915, shown in plan-view and in section. In the pit, the main lake and the northwest pond stand at a level of about 460 feet below the rim. No fountains appeared in either the lake or pond at the time the sketch was made, but streaming (shown by arrows) and splashing at "caves" around the walls of the lake were active as usual.

When the lake falls, it leaves black ledges and walls around the margins, which fall into the lake as the walls are undermined at the lake-level. The degree of tumbling in of the walls immediately around the lake, and even of the main Halemaumau walls, depends upon the amount and rapidity of the subsidence.

The vertical movement of the lava within the pit appears to be controlled to a large extent by the pull of the sun and moon as well as by the physical and chemical forces within the lava and the magma chamber below. It has been observed that at the time of the solstice the lava tends to rise, and at the time of the equinox to fall. Thus, the maximum height of the lava since 1894 was at the time of the winter solstice, January, 1912. In October, 1914, the lake reappeared after a period of quiescence, and rose until the winter solstice, reaching a maximum height of 363 feet on January 4, 1915. With the following equinox, the level dropped to 515 feet on April 3, and thereafter lagged under the solsticial pull, until the first week in June, when a definite rise began, with a level of about 460 feet on June 10. This rising phase should continue until July.

Furthermore, a daily variation of level has been noted, with a high tide at noon and at midnight—tide possibly effected by maximum barometric pressure at those times. This daily movement is relatively small, and not always detectable, but it is at times as much as 40 feet.

The volcano Kilauea is one of the attractions for tourists on the Hawaiian Islands, as the lava lake is clearly visible by day and by night unless the lava is far below the rim, when it may be obscured by sulphurous gases rising from the walls and floor. The crater is accessible by automobile road from Hilo, the largest town on the island of Hawaii, and but 31 miles away. It is seven miles by road from the Volcano Observatory and the Volcano House (Hotel) to the crater, but only three miles by path over the lava of the Kilauea sink.

Mauna Loa is the greatest active volcano in the world for two reasons: its height, 13,675 feet; and its periodic activity, at intervals of about ten years ever since the arrival of the first missionaries on the island. It is a greater volcano than Kilauea nearby, because lava flows, miles in length, pour out of fissures on the sides of the immense broad dome, and frequently run into the sea, 20 to 40 miles away. The last of these flows was in 1907, when a stream of molten rock ran over portions of several older flows, across an uninhabited strip of land, and nearly into the sea. On November

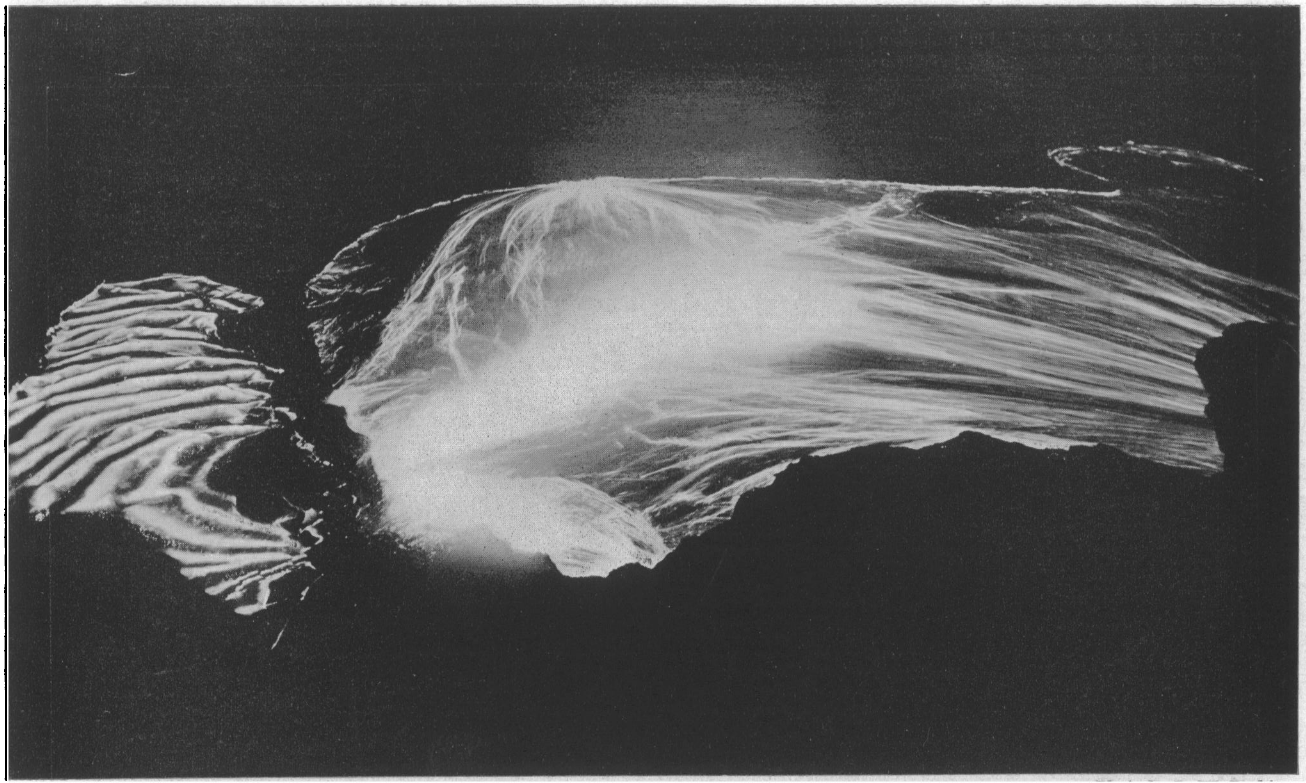

Photo by R. W. Perkins

FIG. 2—The lava lake in Halemaumau as seen in September, 1909, when about 90 feet below the rim of the crater. The lava is streaming toward the left and is overflowing the edge of the lake, onto the floor, producing the flow shown with lines which resemble ripple-marks. The lines are the places where the red lava shows through the thin black crusts of partly cooled lava which cover the surface of the lake.

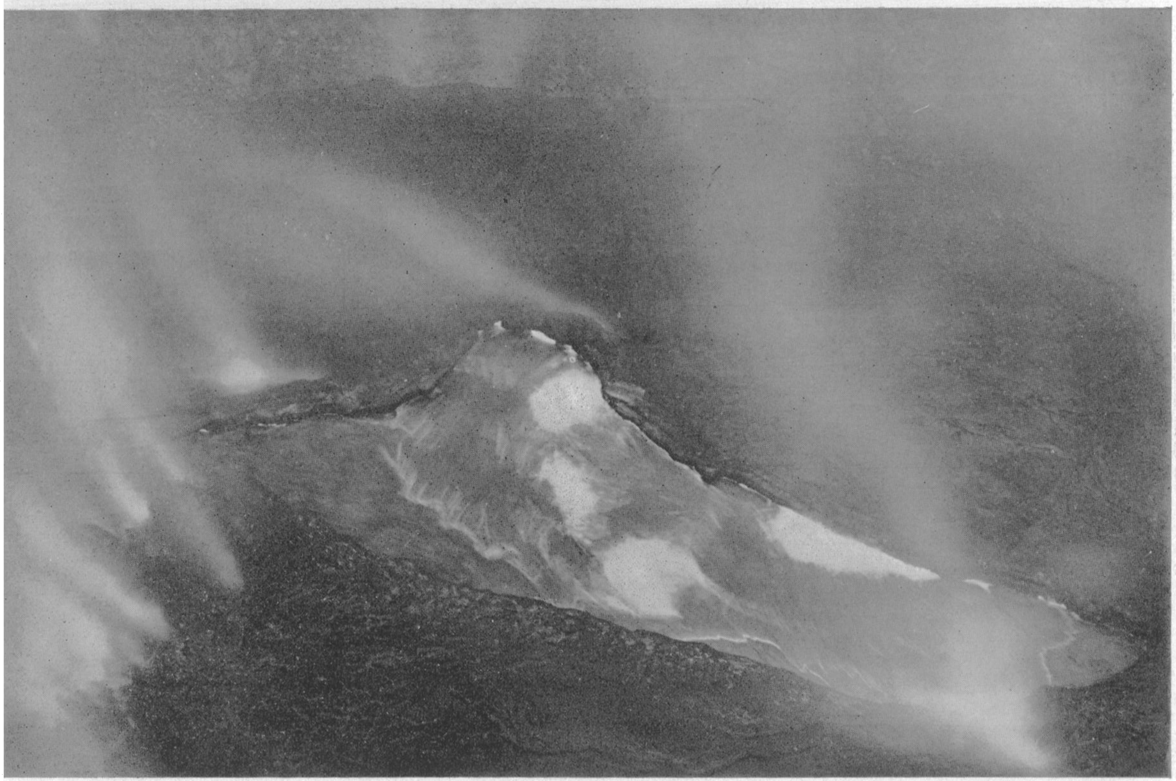

Photo by Chock Chong, Hilo

FIG. 5—The small lake of February, 1915, after subsidence had begun from the level of 363 feet below the rim on January 4. Two fountains are shown bursting in the center of the lake, and a third fountain has migrated to the wall (in the upper part of the picture), to become a splashing "cave." The light-colored area on the right is a "cave."

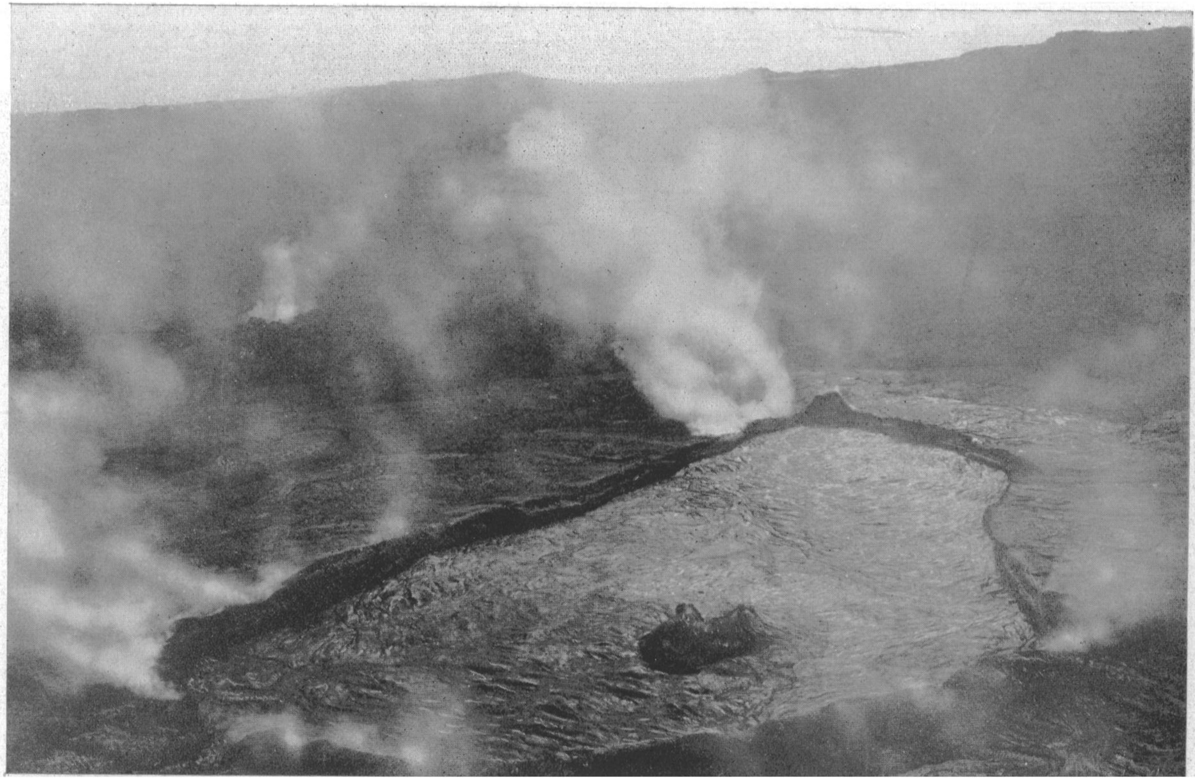

Photo by Chock Chong, Hilo

FIG. 4—The lava lake in February, 1918. The lake has subsided slightly leaving a low wall between the molten lava and the floor of the pit. In the center of the lake a fountain is bursting.

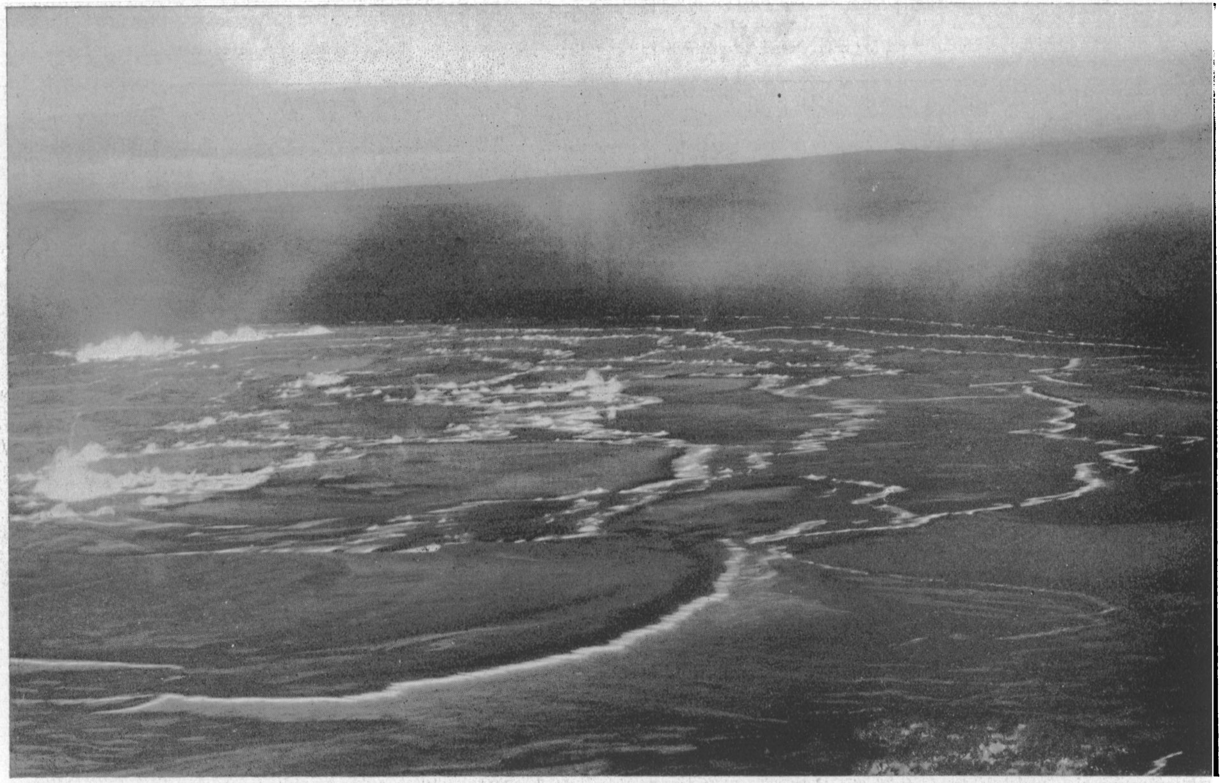

Photo copyrighted by Chock Chong, Hilo, Hawaii

FIG. 3—The lava lake in January, 1912, showing the walls of the pit, above which, in the background, is a portion of the Mauna Loa slope. The lake is about 90 feet below the rim and completely fills the crater. Many fountains are active.

25, 1914, came the next outbreak, this time with only summit activity. A large lava lake developed, with fountains playing both continuously and intermittently to heights of 200 to 400 feet. The volcano was ascended by only a few parties during the 48 days of known activity, because of the difficulty of the trip—a climb of 10,000 feet over the roughest kind of lava, with no water above the half-way camp, except for the snow which covered the summit after November 28; and because of the intense cold and discomfort at the top, with no shelter of any kind from the wind and weather, and no place to sleep except on the bare lava, which is just like a pile of clinkers. Before any scientific work can be done at the summit, it will be necessary to secure funds to build a shelter, both for men and for animals, and to fit the shelter with bunks. As there is no wood within miles of the summit, all fuel must be brought along. Furthermore, the mountain slopes are inhabited by wild cattle—supposed to have been there since the first cattle were landed by Vancouver in 1793; these are sometimes dangerous, and may attack parties on the side of the mountain.

The Hawaiian Volcano Observatory was built in 1912 near the Volcano House on the edge of the Kilauea sink. It comprises the main observatory building, equipped with one large laboratory, and three smaller rooms, with a seismographic cellar 18 feet square; and two small buildings, occupied by the associate and the janitor. At the crater there is a small frame building which was used temporarily for a small seismograph and for other instruments. This building is affected by sulphur smoke, and has been broken into several times by vandals, with the result that it is of use principally as a shelter.

The Whitney Laboratory of Seismology at the observatory is equipped with two Bosch-Omori seismographs, one Omori sensitive seismograph, and an Omori ordinary seismograph which records only very strong earthquakes. The seismographic work is in charge of Mr. H. O. Wood. On account of the rifted nature of the rock upon which the seismographs rest, they do not record many of the distant earthquakes, but the aim of the station is to study the local shocks.

The other laboratories are supplied with drawing tables and instruments, and a dark-room for photographic work. The surveying instruments include a solar transit loaned by the College of Hawaii, an alidade and plane-table loaned by the U. S. Geological Survey, two small Japanese transits, weighing, with the tripod, about six and one-half pounds each, and minor instruments. A rain gauge, maximum and minimum thermometer, barograph, thermograph, and wet and dry bulb hygrometer are kept in suitable places outside the building, and the records are sent to the Weather Bureau.

The immediate aims of the Observatory are to record the varying phases of the activity of Kilauea and the occasional outbursts of Mauna Loa, and the local earthquake shocks; and to compare these with secular, meteorological and astronomical change. For the purpose of the measurement of the Halemaumau pit temporary triangulation stations have been erected around the walls. The depth of the lava is measured by triangulation, but the accuracy of the method depends upon the instrument used, the clearness of the object sighted on (usually a stalactite in front of a splashing cave), and upon the amount of smoke in the pit. The triangulation stations are at present partly constructed of loose lava blocks, which are frequently broken down by visitors as objects to throw into the pit. The height of the lake may change rapidly and the caves may cease splashing at any moment, so, with smoke obscuring the pit, as is often the case, observation is difficult.

The daily routine consists of changing the seismograph records, of taking the meteorological observations, of photographing Halemaumau from the observatory and of observing the lava lake with measurements of the depth and size. This work is more than sufficient to occupy the time of one man throughout the day, and the depth and dimensions of the lake must be computed by plotting in the laboratory. With the lake at a depth of over 450 feet, it may take an entire day to secure a few measurements.

The publications of the Observatory comprise a weekly report which is published in the *Pacific Commercial Advertiser* in Honolulu and in the *Hilo Tribune,* and later in the regular reports of the Observatory published by the Hawaiian Volcano Research Association in Honolulu at a subscription price of $5 a year. An annual report is to be published by the Society of Arts of the Massachusetts Institute of Technology. The first of these reports has been issued, the later ones have been delayed by the lack of clerical assistance in preparation.

The Observatory is supported in part by the income from the Whitney Fund of the Massachusetts Institute of Technology, but principally by private subscription. The Observatory is badly in need of funds for general maintenance, for an assistant and for new instruments, and supplies. It is now necessary for the Director to raise sufficient money to pay the salaries, with the result that the Associate must assume charge of the observations on the lava, as well as the work on the seismographs. An assistant is needed to do the routine work which now occupies so much of the time of those in charge that there is not sufficient opportunity to compile the results of the observations. A large amount of data concerning the levels of the lake and meteorological observations, which must be plotted, now await the aid of an assistant.

The value of the observatory from the standpoint of geology is immense, because this is the only volcano in the world in which there is a liquid lava lake almost all the time, and near which an observatory may be maintained in safety. From the standpoint of service to the people in the vicinity, or to those in other volcanic regions, the observatory is of use in the prediction of volcanic activity, and of the danger of loss of life and property. While there have been only three lava flows from the sides of Kilauea since white men came to the islands, Mauna Loa is periodically active, with a lava lake and immense fountains at the summit (as from November 25, 1914, until Jan. 11, 1915), and later a lava flow from the sides of the volcano. By a careful study of the imperfect records, it has been possible to predict the date of the last activity within a period of three years, and by a comparison of the records of both Mauna Loa and Kilauea, it has been possible to predict the time of activity as at or near the solstice. Within two or three years, a lava flow is predicted by the Observatory staff, to flow down the side of Mauna Loa toward the city of Hilo, the second largest town in the islands. If sufficient funds were available it would be possible to make a topographic map of that side of Mauna Loa to show in just what direction the lava is most likely to run. With careful observations for a number of years, further predictions may be possible.

At the time of the last activity on Mauna Loa, commencing November 25, 1914, a seismic prelude was indicated by the seismograph records; and at the time of the outbreak on the summit reported by cattle men 20 miles away, there was a series of small earthquake shocks, recorded only instrumentally. As this is the first activity on Mauna Loa since the installation of the seismographs, the time of future outbreaks may be foretold more accurately by the prelude of small earthquakes, most of which are only instrumentally perceived.